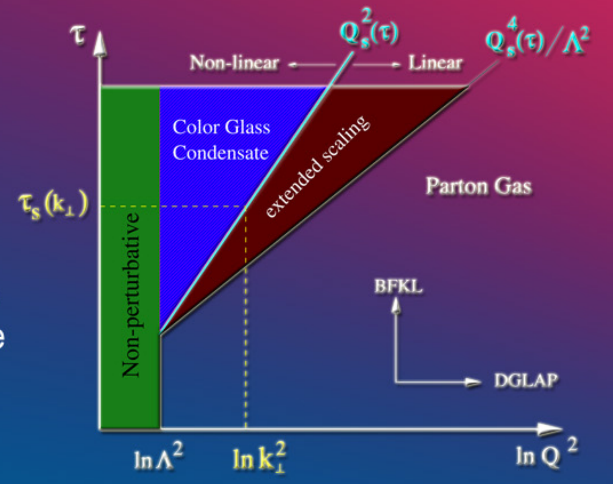
STAR's
Forward Meson Spectrometer (FMS)

Physics Goals

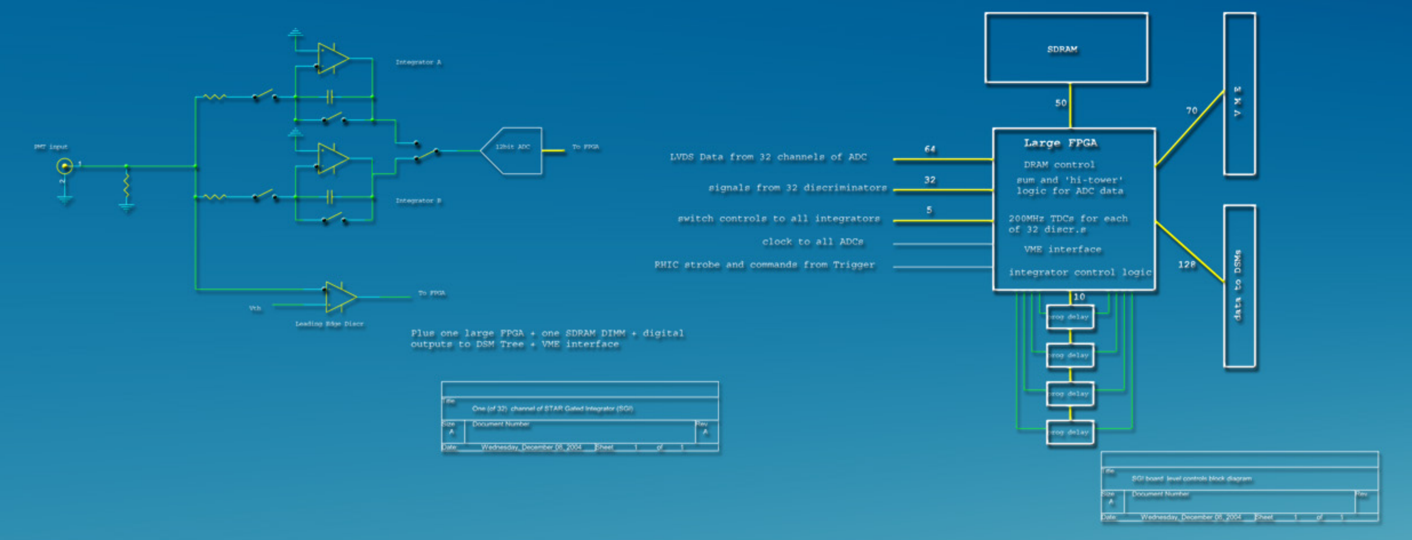
A measurement of the parton model gluon density distributions, $xg(x)$, in gold nuclei for $0.001<x<0.1$. Characterization of $g(x)$ as a function of Q^2 which is expected to reveal gluon saturation effects leading to new models for macroscopic gluon fields. Measurements with transversely polarized protons that will resolve the origin of large transverse spin asymmetries in $p_{\uparrow}+p\to\pi^0+X$ reactions for forward π^0 production.

Among the descriptions of shadowing or saturation effects is the Color Glass Condensate (CGC), an effective field theory aimed at understanding parton saturation. In the CGC picture, the saturation effects are associated with a new phase of the gluon field. The onset of this phase is associated with small x and small Q (related to the produced parton mass and the transverse momentum p_T associated with the scattering).

Mapping out the boundaries for saturation signatures for back-to-back correlations as a function of x and p_T, as shown in the figure on the right, is a primary mission of the FMS. The figure shows the boundary between possible "phase" regions in the $\tau=\ln(1/x)$ vs $\ln(Q^2)$ plane.



Trigger & Readout Electronics



Above are block diagrams of a single input channel (*left*) and a 32 channel board (*right*). Each PMT feeds a separate channel. Each channel feeds both a discriminator and an integrating charge-to-digital converter (ADC). For every RHIC clock cycle of 105ns, one integrator of the ADC's dual integrator front end is active while the other is being reset. At the leading edge of the next clock cycle the integrators are switched and the last active integrator presents its signal to the 12 bit, 40MHZ digitizer. Output from the digitizer is shipped to an FPGA for packaging.

In line with FMS physics goals, the requirements of the electronics design are to provide energy measurement over the accessible range at RHIC with sufficient sensitivity to lead to unambiguous π^0 mass reconstruction while simultaneously rejecting background. The requirements are as follows.

1. Dynamic Range (0-250 GeV) and sensitivity (0.05 GeV)
2. Signal capture (~80ns active capture time)
3. Background suppression (time stamp "hits" with an accuracy of <~5ns)
4. Rate capability (operate at 10 MHZ to match the STAR system)

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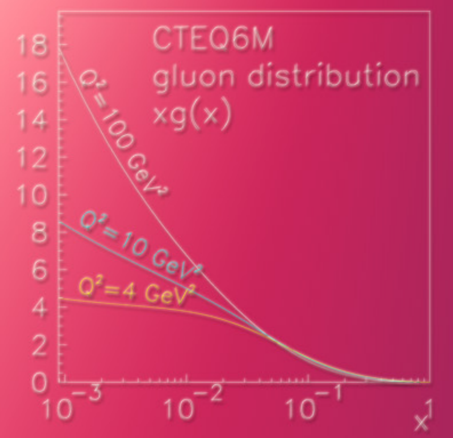
Poster designed by: Vanessa Valdez for the STAR Collaboration.

Quantum Electro Dynamics (QED), has its origin in Maxwell's equations regarding macroscopic electric and magnetic fields. From this arose an early theory of radiation that led to Planck's hypothesis of quantized action and thereby to quantum mechanics. Quantum Chromo-Dynamics (QCD)--the theory of the strong force--describes the dynamics of individual partons equivalent to the "test particles" of electromagnetic theory. QCD does not yet have an analog of Maxwell's equations for macroscopic color fields. Recent evidence from the Relativistic Heavy Ion Collider (RHIC) at Brookhaven National Laboratory (BNL) may lead to such an extension, and perhaps to a fundamental shift in our understanding of the strong force in the nucleus.

The Solenoidal Tracker at RHIC (STAR) is designed to detect charged particles produced in relativistic heavy ion interactions. Use of STAR's various detectors has yielded comprehensive measurements of p+p, d+Au, and Au+Au interactions. Combined experimental data from RHIC suggests that the small x gluon distribution in a large nucleus like gold is reduced, or shadowed, from the nominal superposition of the distributions of the included protons and neutrons, a phenomenon described as saturation.

STAR intends to exploit capabilities of some of its existing detectors (time-projection chamber, barrel and endcap electronic calorimeters, and foward pion detector) and build a FMS to enable measurement of the gluon distribution, $xg(x)$, in nuclei in the range $0.001<x<0.1$.(1) The function $g(x)$ gives the probability to find gluons, the carriers of the strong force, with a fraction x of the longitudinal momentum of the parent proton or neutron. At very low x the gluons begin to act collectively--suggesting that a new macroscopic field description for QCD may become necessary.



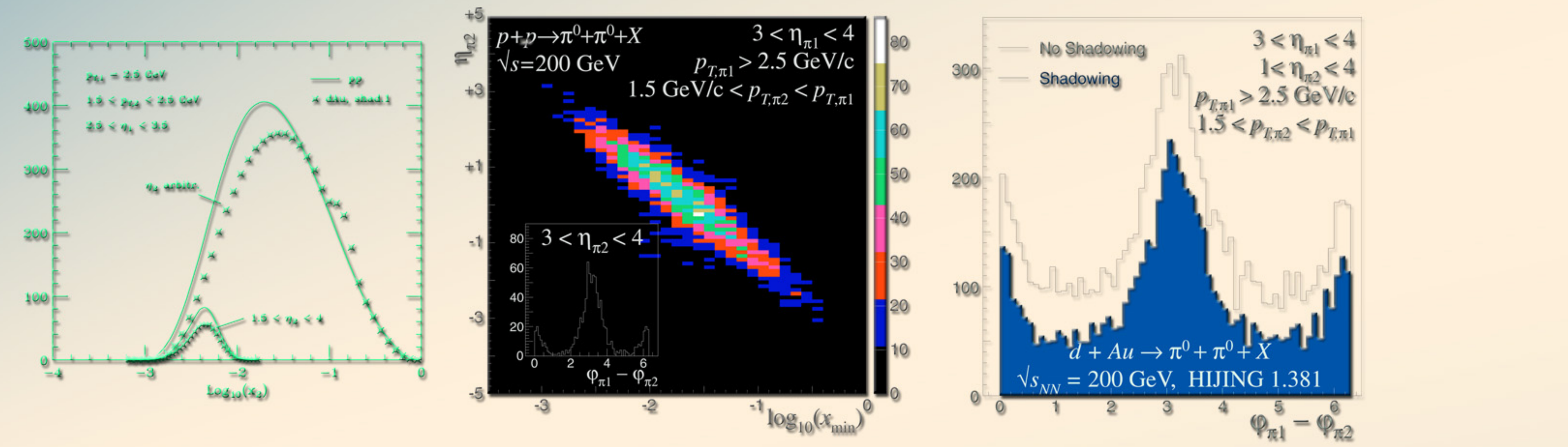
(1) The figure on the ***left*** shows recently published nucleon gluon distributions. Note the rapid rise in $xg(x)$ for $x<0.01$, a discovery made at HERA based on studies of deep inelastic scattering (DIS), using electron (positron) + proton collisions at $\sqrt{s}$=300 GeV.

FMS Highlights

Nearly hermetic electromagnetic coverage at STAR in the range $-1<\eta<4$ (polar angle range $2<\theta<130°$).

Correlation measurements between forward mesons and photons with signals from the full STAR detector.

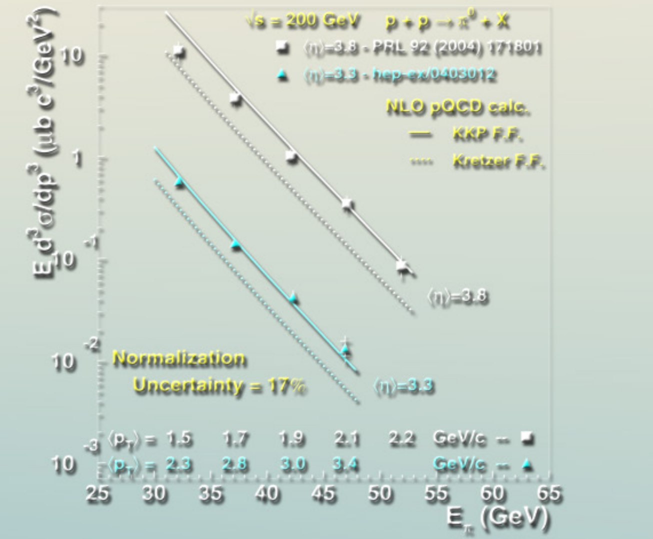
Measurement of the gluon density in protons and in nuclei down to x~0.001.



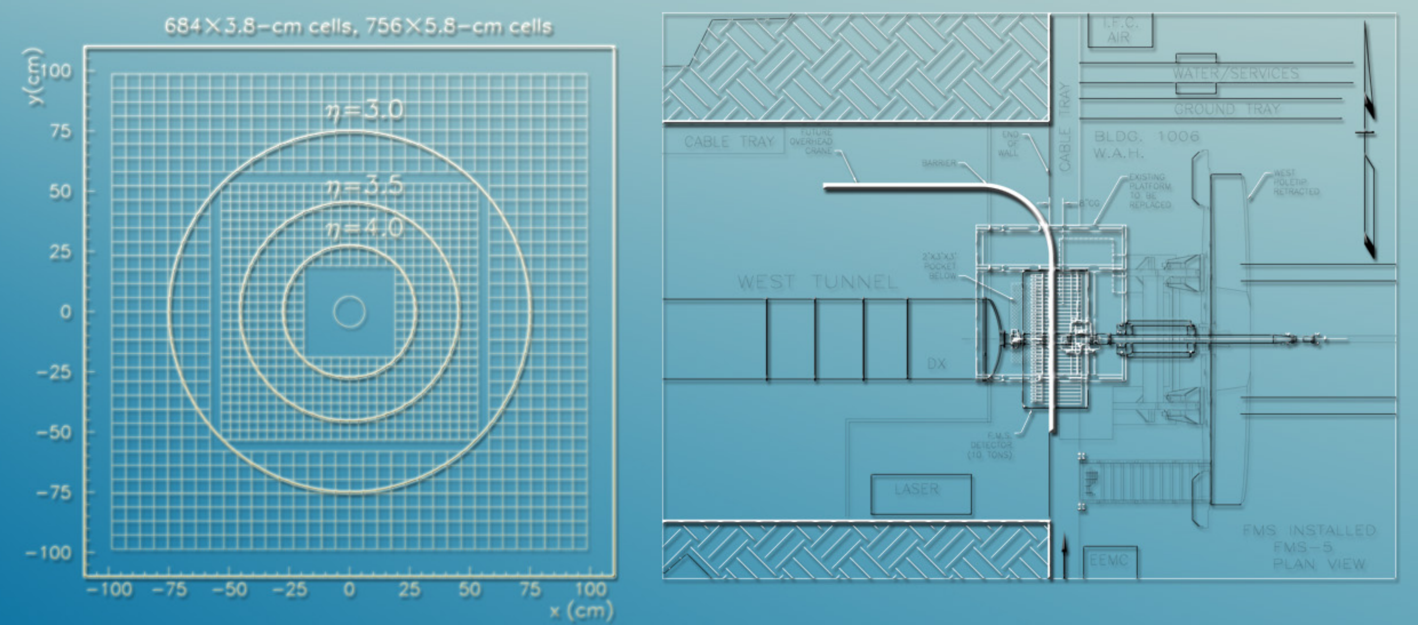
Recent measurements at STAR using the prototype Forward Pion Detector (FPD) indicate that factorized leading twist perturbative QCD (pQCD) calculations work well to predict the $p+p\to\pi^0+X$ cross section in the rapidity 3 to 4 region. This gives confidence in the interpretation that at $\sqrt{s}$=200 GeV the process is dominated by leading twist quark-gluon scattering.

With the FMS focusing on π^0 pairs, we will select the small-x component shown by Next-to-Leading-Order (NLO) pQCD calculations in the *left panel* above to make only small contributions to the inclusive measurement. The small-x component of the forward pion yield is where shadowing effects ae expected to be most important. In the *middle panel* above, we see that when triggering on a π^0 in the range $3<\eta<4$, the rapidity of the second π^0 will reflect the x of the struck gluon. The *right panel* above shows that elastic parton scattering can be identified above physics backgrounds in d+Au collisions.

The *right* figure shows invariant cross sections for inclusive π^0 production at $\langle\eta\rangle$=4.0 in d+Au collisions at $\sqrt{s}$=200 GeV compared to NLO pQCD calculations. These preliminary results were obtained with an FPD positioned close to the beam. Like the FMS, the FPD allows for robust indentified π^0 measurements, including its energy and direction. Since the π^0 is a pseudoscalar particle, kinematic distributions of its diphoton decay are exactly calculable in any frame of reference. The technique of requiring a fully consistent response of all of the cells of the calorimeter to the photons produced by the $\pi^0\to\gamma\gamma$ decay will be used to calibrate the FMS response time.



FMS Configuration



Left is an elevation view of the west side of the STAR Wide Angle Hall (WAH). The FMS is mounted at the opening of the RHIC tunnel into the west side of the WAH. The location shown is 7.5m from the STAR interaction point.

Above left is a schematic of the FMS layout as seen from the STAR interaction point looking west. The FMS is comprised of inner and outer calorimeters (IC,OC) that surround the beam, mounted at a longitudinal distance of 7.5m from the STAR interaction point. The IC is made from a square annulus of 3.8cm x 3.8cm x 45cm optically isolated lead-glass cells, each viewed by a FEU-84 photomultiplier tube (PMT). The OC is made from a square annulus of 5.8cm x 5.8cm x 60cm optically isolated lead-glass cells, each viewed by a XP2202 PMT. The resulting FMS has an areal coverage of 2m x 2m.